

# MultiConnect® mDot™

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## MTDOT Developer Guide

## MultiConnect mDot Developer Guide

Models: MTDOT-915-xxx, MTDOT-868-xxx includes also the MTUDK2-ST-MDOT Developer Kit

Part Number: S000612, Version 1.2

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# Chapter 1 Product Overview

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## Overview

The MultiConnect mDot is a secure, programmable, long-range RF module that provides data connectivity to sensors, industrial equipment, and remote appliances. By using the Semtech LoRa™ Long Range Spread Spectrum technology, bi-directional data communication can be maintained over 10 miles/16 km, deep into buildings and within noisy environments using the unlicensed ISM bands in North America, Europe and worldwide. mDot simplifies local connectivity for Internet of Things (IoT) applications.

The mDot features an integrated ARM® Cortex®-M4 processor and mbed™ compatible software library for developers to control, monitor and bring edge intelligence to their Internet of Things (IoT) applications.

## Documentation Overview

This manual is one part of mDot documentation. Refer to the *Related Documentation* and *mbed* sections for additional information needed to program your mDot and integrate your application with the MultiConnect Conduit gateway.

This document includes the following sections:

- **mDot device information:** Mechanical drawings, specifications, safety and regulatory information, and other device specific content. Chapters 1-8
- **Universal Developer Kit information:** Using the MTUDK-ST-MDOT Developer Kit, including design considerations, schematics, and installation and operation information. Chapters 9-13
- **AT commands:** Includes both MultiTech and Xbee Zigbee AT Command sets. Chapters 14-15.

This manual is available at [www.multitech.com/support](http://www.multitech.com/support).

## Related Documentation

Use cases, application notes, LoRa information, and documentation for related products such as the MultiConnect Conduit (MTCDDT) gateway and the LoRa accessory card (MTAC-LORA) are available on the MultiTech developer site. This site information on using the Conduit with mDots. Go to:

[www.multitech.net](http://www.multitech.net)

## mbed Documentation

ARM mbed is a free, open-source platform and operating system for embedded devices using the ARM Cortex-M microcontrollers. The mbed website provides free software libraries, hardware designs, and online tools for rapid prototyping of products. The platform includes a standards-based C/C++ SDK, a microcontroller HDK, and supported development boards, an online compiler and online developer collaboration tools.

**Note:** To use the mDot mbed code, you need a LoRaWAN 1.0 gateway, such as MultiTech's MultiConnect Conduit (MTCDDT) with an MTAC-LORA accessory card installed.

## Programming the mDot Microcontroller

With the mDot and the MTUDK2-ST-xx developer board, use the ARM mbed ecosystem to program the microcontroller. Compile in the cloud or locally, copy the resulting binary file to the mbed USB drive, and reset the mDot.

**Note:** To program the mDot, you need an mDot model with programming header.

On the mDot mbed page, MultiTech supplies source code for non-RF portions of the mDot and MTAC-LORA cards. To comply with FCC and ETSI certification, some portions of the software will be available only as binary libraries.

## mBed Links

- Explore mbed: <http://developer.mbed.org/explore>
- Getting Started with mbed: <http://developer.mbed.org/getting-started>
- mbed Handbook: <http://developer.mbed.org/handbook/Homepage>

## mDot Platform

The mDot mbed page includes the mDot library and test cases <https://developer.mbed.org/platforms/MTS-mDot-F411>

## EUI and Networking

All mDots have a factory-programmed Extended Unique Identifier (EUI). This is marked as **Node** on the mDot label.

To connect an mDot to a network, you will need to program it with the network ID for the network you are connecting to as well as the network key and application key. For information on setting up mDots as part of a LoRa network, go to: [www.multitech.net](http://www.multitech.net)

## Product Build Options

Product	Description	Quantity to Order
<b>North America</b>		
MTDOT-915-X1-SMA	915 MHz XBee LoRa SMA	1 or 50
MTDOT-915-X1P-SMA	915 MHz XBee LoRa SMA with Programming Header	1
MTDOT-915-X1-UFL	915 MHz XBee LoRa U.FL	1 or 50
MTDOT-915-M1-UFL	915 MHz SMT LoRa U.FL	1 or 100
MTDOT-915-M1-TRC	915 MHz SMT LoRa RF Pad	1 or 100
<b>EMEA</b>		
MTDOT-868-X1-SMA	868 MHz XBee LoRa SMA	1 or 50
MDOT-868-X1P-SMA	868 MHz XBee LoRa SMA with Programming Header	1
MTDOT-868-X1-UFL	868 MHz XBee LoRa U.FL	1 or 50
MTDOT-868-M1-UFL	868 MHz SMT LoRa U.FL	1 or 100
MTDOT-868-M1-TRC	868 MHz SMT LoRa RF Pad	1 or 100
<b>Developer Kits</b>		
MTUDK2-ST-MDOT	mDot Developer Kit	1

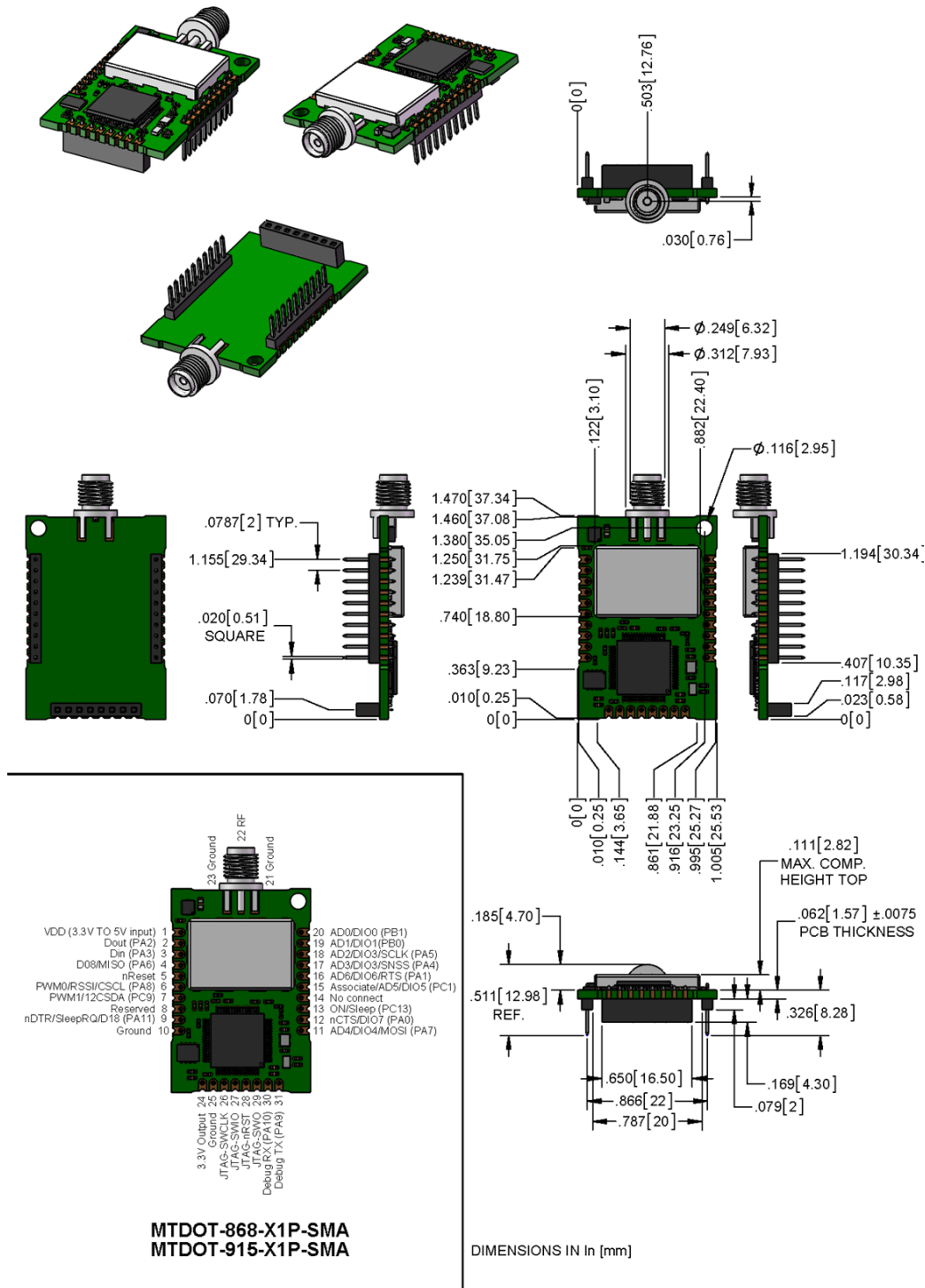
**Note:**

- The complete product code may end in .Rx. For example, MTDOT-915-M1-X1.Rx, where R is revision and x is the revision number.

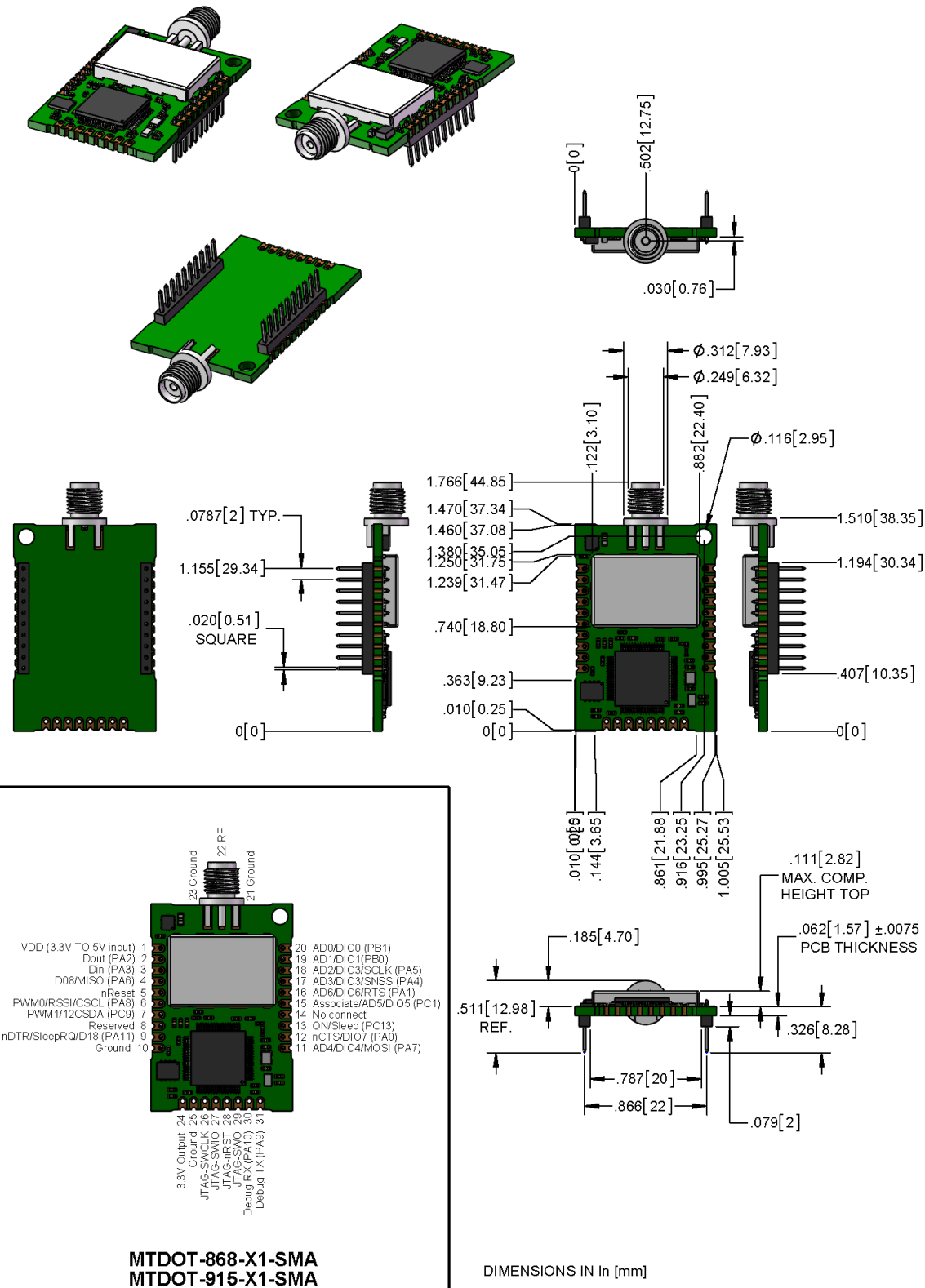


# Chapter 2 Mechanical Drawings with Pinouts

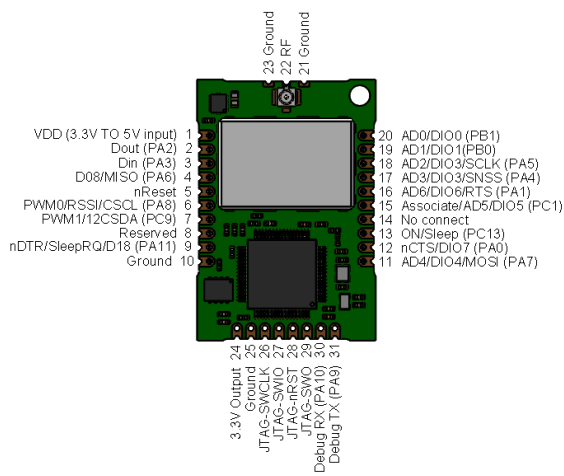
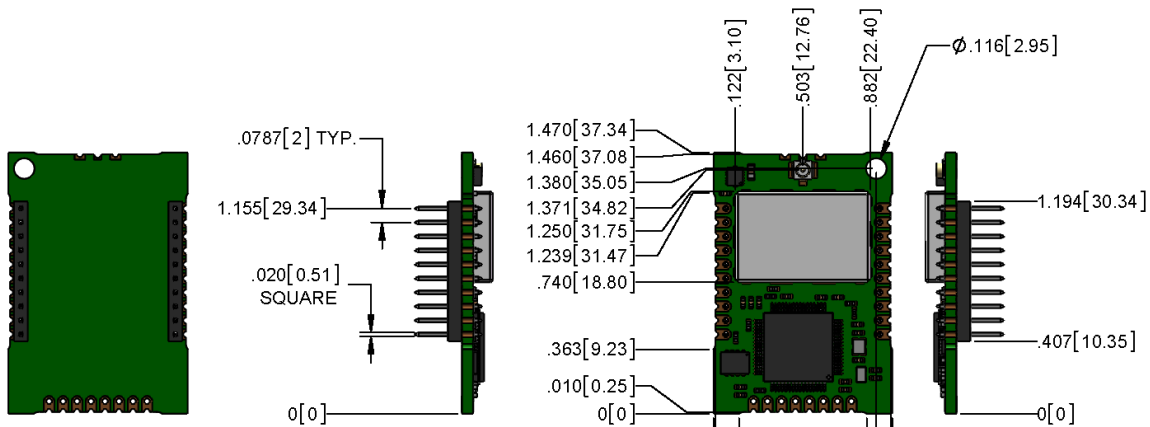
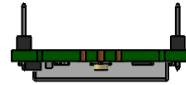
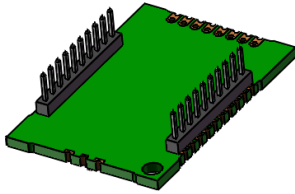
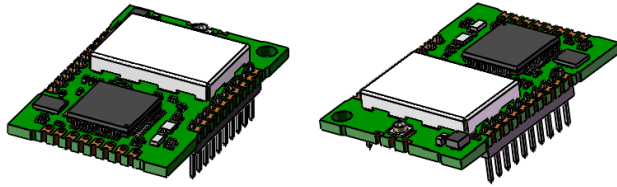
## MTDOT-xxx-XP1-SMA



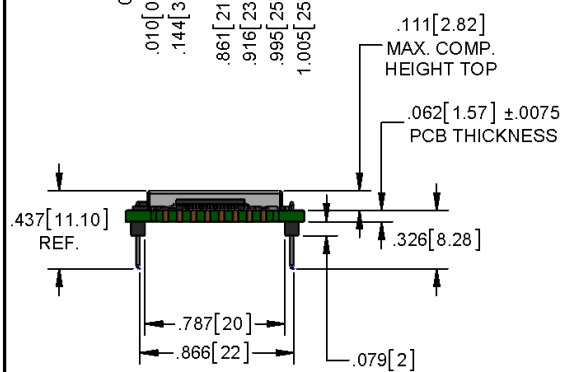
# MTDOT-xxx-X1-SMA



# MTDOT-xxx-X1-UFL

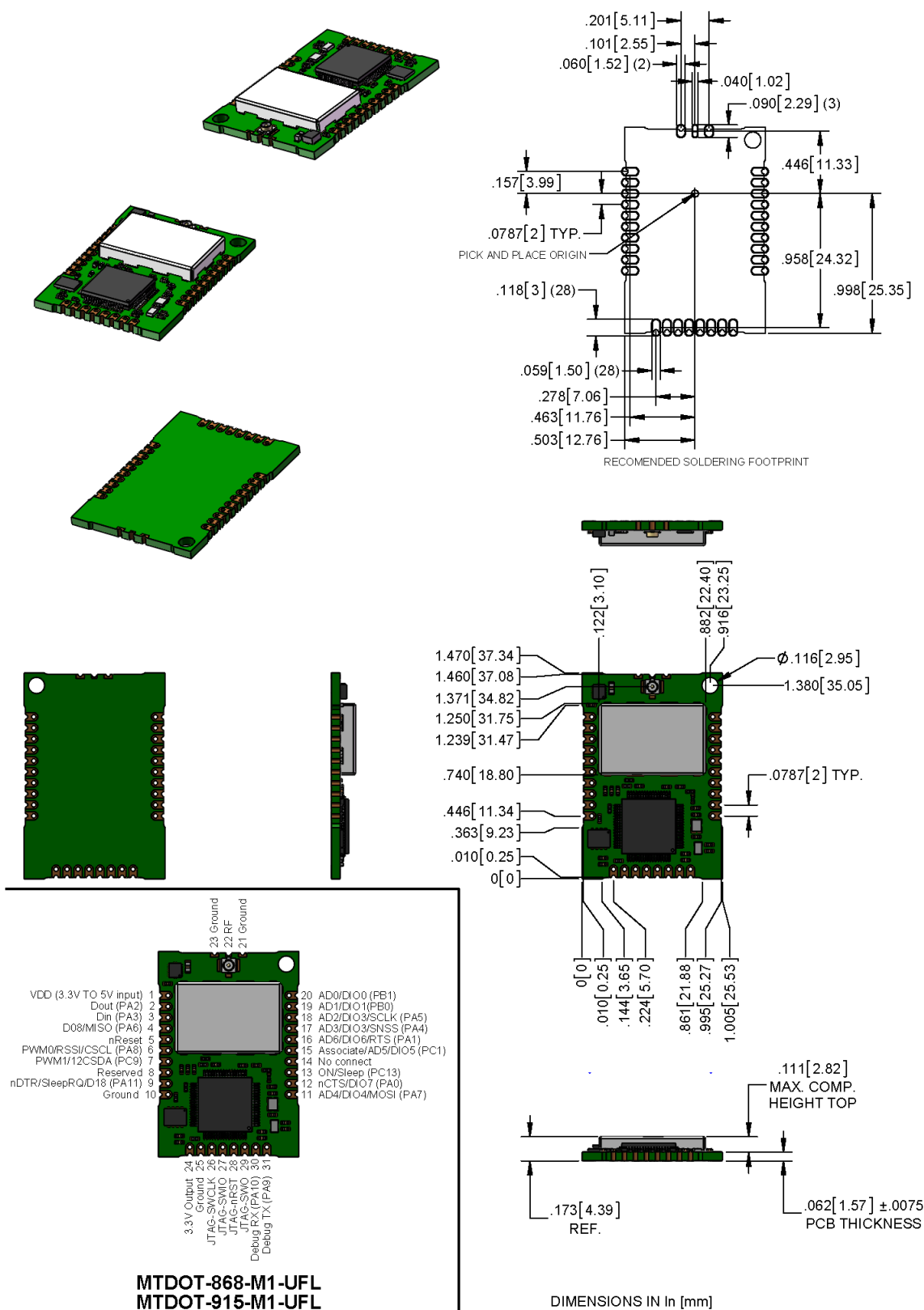


MTDOT-868-X1-UFL  
MTDOT-915-X1-UFL

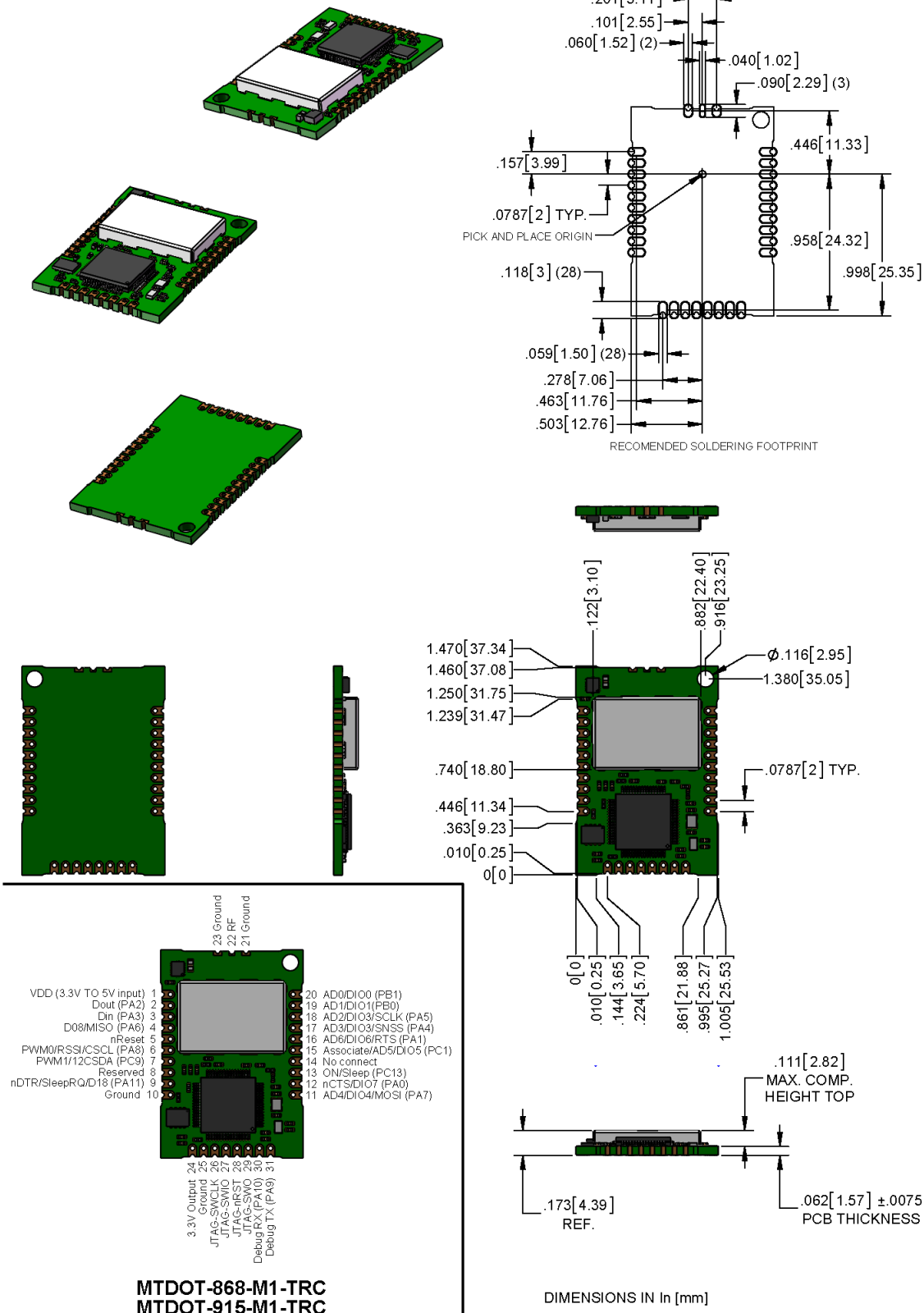


DIMENSIONS IN In [mm]

# MTDOT-xxx-M1-UFL



# MTDOT-xxx-M1-TRC



# Chapter 3 Specifications

## MTDOT Specifications

Category	Description
<b>General</b>	
Compatibility	LoRaWAN 1.0 specifications
Interfaces	Note that pin functions are multiplexed.
	Up to 16 digital I/O
	Up to 11 analog inputs
	SPI
	I2C
	UART (RX, TX, RTS, CTS)
	USB (OTG full speed)
<b>CPU Performance</b>	
CPU	STM32
Max Clock	100 MHz (configurable to control power use)
Flash Memory	512 KB (400 KB available)
RAM	128 KB
<b>Radio Frequency</b>	
ISM Bands	863 MHz - 868 MHz, 902 MHz - 928 MHz
<b>Physical Description</b>	
Weight <sup>1</sup>	0.2 oz. (5g)
Dimensions	Refer to Mechanical Drawings for Dimensions.
<b>Connectors</b>	
-SMA Models	SMA
-UFL Models	U.FL
-Trace Models	Trace Connection
<b>Environment</b>	
Operating Temperature	-40° C to +85° C
Storage Temperature	-40° C to +85° C
Humidity	20%-90% RH, non-condensing
<b>Power Requirements</b>	
Operating Voltage	3.3 V
Input Power	3.3 VDC

Category	Description	
Transmission		
	North America	EMEA
Max Transmitter Power Output (TPO)	15 dBm	14 dBm
Maximum Receive Sensitivity	-130 dBm	-137 dBm
Link Budget <sup>2</sup>	154 dB Point-to-Multipoint <sup>3</sup> , 147 dB Point-to-Point	145 dB Point-to-Multipoint, 147 dB Point-to-Point
Max Effective Isotropic Radiated Power (EiRP)	36 dBm	10 dBm
Certifications and Compliance		
EMC Compliance	EN 300 220-2 V2.4.1:2012	
	EN 301 489-03 V1.6.1:2013	
Radio Compliance	FCC 15.247:2015	
	FCC 15.109:2015	
	FCC 15.107:2015	
	RSS-210:2010	
	ICES-003:2012	
	CISPR 22:2008	
	EN 300 220-2 V2.4.1:2012	
Safety Compliance	UL 60950-1 2nd ED	
	cUL 60950-1 2nd ED	
	IEC 60950-1 2nd ED AM1 + AM2	

<sup>1</sup>Weight is for the MTDOT-xxx-X1P-SMA, which is the heaviest model.

<sup>2</sup>Greater link budget is possible with higher gain antenna.

<sup>3</sup>Point-to-Multipoint using MultiTech Gateway with MT-LORA accessory card

## Power Draw

### Note:

- Power measured with the mDot installed on the MTUDK2 developer board. MTUDK2 supplied 3.3 VDC to the mDot.
- Power measured with mDot spreading factor (SF) set to 9.

- Transmit power measured with mDot transmitting to a MultiConnect Conduit with an MTAC-LORA accessory card installed. Distance separating the Conduit from the mDot was 18 inches.

Voltage	Packet Size	Average Current (Amps) at Low Transmit Power Setting (TXP 2)	Average Current (Amps) at Default Transmit Power Setting (TXP 11)	Total Inrush Charge Measured in Millicoulombs (mC)	Total Inrush Charge Duration during Powerup (mS)
<b>3.3</b>	10	0.019	0.020	2.15	1.098
	230	0.029	0.029	2.15	1.098

## DC Characteristics

Signal	Description	Min	Max
Vin Low	Input low level	--	.99
Vin High	Input high level	2.31	--
Vout Low	Output low level	--	.4
Vout High	Output high level	2.9	--
VCC	Standard operating voltage	3.3	5
ICC <sup>1</sup>	Operating current (mA) @5V	--	135
	Operating current (mA) @3.3V	--	200

## Pin Information

Using the mbed platform with the Cortex-M4 processor expands your pin functionality options. Refer to the document, mDot Pin Function Mapping, which is available at [www.multitech.net/developer/multiconnect-mdot](http://www.multitech.net/developer/multiconnect-mdot) and <https://developer.mbed.org/platforms/MTS-mdot-f411/> for details.

MT Pin	Base Number (Where applicable)	Description
1		3.3 to 5 V input
2	PA2	Dout
3	PA3	Din
4	PA6	D08/MISO
5		nReset
6	PA8	PWM0/RSSI/CSC L



MT Pin	Base Number (Where applicable)	Description
7	PA9	PWM1/12CSDA
8		Reserved
9	PA11	nDTR/SleepRQ/D18
10		Ground
11	PA7	AD4/DIO4/MOSI
12	PA0	nCTS/DIO7
13	PC13	ON/Sleep
14		No connect
15	PC1	Associate/AD5/DIO5
16	PA1	AD6/DIO6/RTS
17	PA4	AD3/DIO3/SNSS
18	PA5	AD2/DIO3/SCLK
19	PB0	AD1/DIO1
20	PB1	AD0/DIO0
21		Ground
22		RF
23		Ground
24		3.3V output
25		Ground
26		JTAG-SWCLK
27		JTAG-SWIO
28		JTAG-nRST
29		JTAG-SWO
30	PA10	Debug RX
31	PA9	Debug TX

## mDot Pinout Design Notes

Refer to the mechanical drawing for your model for pin locations.

- All pins that go to connectors are direct connect.
- Reset is the only pin with pull up.
- I/O is 5V tolerant.

mDots allow you to program pins depending on your application:

- **Serial:** Available out of the box. See Serial Pinout Notes for details.
- **Xbee:** Comforms to the Xbee pinout.
- **mbed:** Designed with the mbed STM32F411 RET 64-pin processor, this option provides the most flexibility. For more information about processor capabilities, see the STM32F411 RET datasheet.

**Note:** To program the mDot, you need an mDot model with programming header.

### Serial Pinout Notes

Out of the box, these pins are available for serial applications. Refer to the mechanical drawing for your model for pin locations.

- 2 Dout/TX
- 3 Din/RX
- 9 DTR
- 12 CTS
- 13 On/Sleep
- 16 RTS

## LoRa

### Data Rates

Theoretical maximum speeds for LoRa mode with ACKs off are:

- Using spreading factor 7 at 125kHz, the data rate is 5470 bps (5.47 kbps).
- Using spreading factor 7 at 500kHz the data rate is 21900 bps (21.9 kbps).

### Range

Variables effecting the mDot range include TX power, antenna gain, RX sensitivity, fade margin, earth's curvature. Use the following formula to calculate the maximum range:

$$Range_{Miles} = 10^{\left( \frac{TxPower + Antenna\ gain\ total - RX\ Sensitivity - Fade\ Margin - 36.56}{20} - LOG_{10}(F_{MHz}) \right)}$$

The following table provides example settings and the theoretical maximum range based on these settings.

Example	18dB Transmit Power for 915 MHz Models	Units	Example 14dB Transmit Power for 868MHz Models
Frequency	915	MHz	868

Example	18dB Transmit Power for 915 MHz Models	Units	Example 14dB Transmit Power for 868MHz Models
TX Power	18	dBm	14
TX Antenna Gain	3	dB	3
RX Sensitivity	-120	dBm	-120
RX Antenna Gain	3	dB	3
Fade Margin	30	dB	30
Distance	8.14	Miles	5.41
Distance	13.08	Km	8.70

## Chapter 4 Antennas

### Antenna System

The LoRa antenna performance depends on the implementation and antenna design. The integration of the antenna system into the product is a critical part of the design process; therefore, it is essential to consider it early so the performance is not compromised. If changes are made to the device's certified antenna system, then recertification will be required.

### Pulse Electronics Antenna

Manufacturer:	Pulse Electronics
Description:	868-915 MHz RP-SMA Antenna, 8"
Model Number:	W1063
MultiTech Part Number:	45009830L

#### MultiTech ordering information:

Ordering Part Number	Quantity
AN868-915A-1HRA	1
AN868-915A-10HRA	10
AN868-915A-50HRA	50

### Antenna Specifications

Category	Description
Frequency Range	868-928 MHz
Impedance	50 Ohms
VSWR	$\leq 2.0$
Gain	3.0 dBi
Radiation	Omni
Polarization	Vertical

### OEM Integration

#### FCC & IC Information to Consumers

The user manual for the consumer must contain the statements required by the following FCC and IC regulations: 47 C.F.R. 15.19(a)(3), 15.21, 15.105 and RSS-Gen Issue 3, Dec 2010; 7.1.2 and 7.1.3

#### FCC Grant Notes

The OEM should follow all the grant notes listed below. Otherwise, further testing and device approvals may be necessary.

## FCC Definitions

**Portable: (§2.1093)** — A portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user.

**Mobile: (§2.1091)** — A mobile device is defined as a transmitting device designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons.

**Actual content pending Grant:** *This device is a mobile device with respect to RF exposure compliance. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons, and must not be collocated or operate in conjunction with any other antenna or transmitter except in accordance with FCC multi-transmitter product guidelines. Installers and end-users must be provided with specific information required to satisfy RF exposure compliance for installations and final host devices. (See note under Grant Limitations.) Compliance of this device in all final host configurations is the responsibility of the Grantee.*

**Note:** Host design configurations constituting a device for portable use (<20 cm from human body) require separate FCC/IC approval.

## Host Labeling

The following statements are required to be on the host label:

This device contains FCC ID: {Add the FCC ID of the specific device}

This device contains equipment certified under IC ID: {Add the IC ID of the specific device}

For additional labeling requirements, see the product's Labeling Requirements. For the FCC and IC IDs, see specific certificate information in the Regulatory Statement chapter.

# Chapter 5 Safety Information

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## Handling Precautions

To avoid damage due to the accumulation of static charge, use proper precautions when handling any cellular device. Although input protection circuitry has been incorporated into the devices to minimize the effect of static build-up, use proper precautions to avoid exposure to electronic discharge during handling and mounting the device.

## Radio Frequency (RF) Safety

Due to the possibility of radio frequency (RF) interference, it is important that you follow any special regulations regarding the use of radio equipment. Follow the safety advice given below.

- Operating your device close to other electronic equipment may cause interference if the equipment is inadequately protected. Observe any warning signs and manufacturers' recommendations.
- Different industries and businesses restrict the use of cellular devices. Respect restrictions on the use of radio equipment in fuel depots, chemical plants, or where blasting operations are in process. Follow restrictions for any environment where you operate the device.
- Do not place the antenna outdoors.
- Switch OFF your wireless device when in an aircraft. Using portable electronic devices in an aircraft may endanger aircraft operation, disrupt the cellular network, and is illegal. Failing to observe this restriction may lead to suspension or denial of cellular services to the offender, legal action, or both.
- Switch OFF your wireless device when around gasoline or diesel-fuel pumps and before filling your vehicle with fuel.
- Switch OFF your wireless device in hospitals and any other place where medical equipment may be in use.

## Sécurité relative aux appareils à radiofréquence (RF)

À cause du risque d'interférences de radiofréquence (RF), il est important de respecter toutes les réglementations spéciales relatives aux équipements radio. Suivez les conseils de sécurité ci-dessous.

- Utiliser l'appareil à proximité d'autres équipements électroniques peut causer des interférences si les équipements ne sont pas bien protégés. Respectez tous les panneaux d'avertissement et les recommandations du fabricant.
- Certains secteurs industriels et certaines entreprises limitent l'utilisation des appareils cellulaires. Respectez ces restrictions relatives aux équipements radio dans les dépôts de carburant, dans les usines de produits chimiques, ou dans les zones où des dynamitages sont en cours. Suivez les restrictions relatives à chaque type d'environnement où vous utiliserez l'appareil.
- Ne placez pas l'antenne en extérieur.
- Éteignez votre appareil sans fil dans les avions. L'utilisation d'appareils électroniques portables en avion est illégale: elle peut fortement perturber le fonctionnement de l'appareil et désactiver le réseau cellulaire. S'il ne respecte pas cette consigne, le responsable peut voir son accès aux services cellulaires suspendu ou interdit, peut être poursuivi en justice, ou les deux.
- Éteignez votre appareil sans fil à proximité des pompes à essence ou de diesel avant de remplir le réservoir de votre véhicule de carburant.

- Éteignez votre appareil sans fil dans les hôpitaux ou dans toutes les zones où des appareils médicaux sont susceptibles d'être utilisés.

## Interference with Pacemakers and Other Medical Devices

### Potential interference

Radiofrequency energy (RF) from cellular devices can interact with some electronic devices. This is electromagnetic interference (EMI). The FDA helped develop a detailed test method to measure EMI of implanted cardiac pacemakers and defibrillators from cellular devices. This test method is part of the Association for the Advancement of Medical Instrumentation (AAMI) standard. This standard allows manufacturers to ensure that cardiac pacemakers and defibrillators are safe from cellular device EMI.

The FDA continues to monitor cellular devices for interactions with other medical devices. If harmful interference occurs, the FDA will assess the interference and work to resolve the problem.

### Precautions for pacemaker wearers

If EMI occurs, it could affect a pacemaker in one of three ways:

- Stop the pacemaker from delivering the stimulating pulses that regulate the heart's rhythm.
- Cause the pacemaker to deliver the pulses irregularly.
- Cause the pacemaker to ignore the heart's own rhythm and deliver pulses at a fixed rate.

Based on current research, cellular devices do not pose a significant health problem for most pacemaker wearers. However, people with pacemakers may want to take simple precautions to be sure that their device doesn't cause a problem.

- Keep the device on the opposite side of the body from the pacemaker to add extra distance between the pacemaker and the device.
- Avoid placing a turned-on device next to the pacemaker (for example, don't carry the device in a shirt or jacket pocket directly over the pacemaker).

## Device Maintenance

When maintaining your device:

- Do not attempt to disassemble the device. There are no user serviceable parts inside.
- Do not expose your device to any extreme environment where the temperature or humidity is high.
- Do not expose the device to water, rain, or spilled beverages. It is not waterproof.
- Do not place the device alongside computer discs, credit or travel cards, or other magnetic media. The information contained on discs or cards may be affected by the device.
- Using accessories, such as antennas, that MultiTech has not authorized or that are not compliant with MultiTech's accessory specifications may invalidate the warranty.

If the device is not working properly, contact MultiTech Technical Support.

## User Responsibility

Respect all local regulations for operating your wireless device. Use the security features to block unauthorized use and theft.

## Chapter 6 Regulatory Information

### EMC, Safety, and R&TTE Directive Compliance



The CE mark is affixed to this product to confirm compliance with the following European Community Directives:

Council Directive 2004/108/EC of 15 December 2004 on the approximation of the laws of Member States relating to electromagnetic compatibility;

and

Council Directive 2006/95/EC of 12 December 2006 on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits;

and

Council Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment;

and

Council Directive 1999/5/EC of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

### 47 CFR Part 15 Regulation Class B Devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

**Warning:** Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

### FCC Interference Notice

Per FCC 15.19(a)(3) and (a)(4) This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

### FCC Notice

The MTDOT-x family of products are open development based products that contain a sub ghz radio technology. MultiTech has certified for compliance with US and Foreign compliance bodies including FCC, R&TTE and others. (e.g. FCC 15.247:2015 & IC RSS-210:2010)



MultiTech provides software code meant to operate the radio to a level that maintains compliance with the operating modes under which these radio devices were certified. To ensure this level of compliance, the software code is provided in binary form only. Users are prohibited from making any changes that affect the operation of the radio performance. Accessing or controlling the radio through any means other than the provided binary software will require the user to obtain their own intentional radiator license from the certification body governing their locality, as all precertification provided with mDot will have been made invalid.

## Industry Canada Class B Notice

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la classe B respecte toutes les exigences du Règlement Canadien sur le matériel brouilleur.

This device complies with Industry Canada RSS Appliance radio exempt from licensing. The operation is permitted for the following two conditions:

1. the device may not cause harmful interference, and
2. the user of the device must accept any interference suffered, even if the interference is likely to jeopardize the operation.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

1. l'appareil ne doit pas produire de brouillage, et
2. l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

## Chapter 7 Environmental Notices

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### Waste Electrical and Electronic Equipment Statement

**Note:** This statement may be used in documentation for your final product applications.

#### WEEE Directive

The WEEE Directive places an obligation on EU-based manufacturers, distributors, retailers, and importers to take-back electronics products at the end of their useful life. A sister directive, ROHS (Restriction of Hazardous Substances) complements the WEEE Directive by banning the presence of specific hazardous substances in the products at the design phase. The WEEE Directive covers all MultiTech products imported into the EU as of August 13, 2005. EU-based manufacturers, distributors, retailers and importers are obliged to finance the costs of recovery from municipal collection points, reuse, and recycling of specified percentages per the WEEE requirements.

#### Instructions for Disposal of WEEE by Users in the European Union

The symbol shown below is on the product or on its packaging, which indicates that this product must not be disposed of with other waste. Instead, it is the user's responsibility to dispose of their waste equipment by handing it over to a designated collection point for the recycling of waste electrical and electronic equipment. The separate collection and recycling of your waste equipment at the time of disposal will help to conserve natural resources and ensure that it is recycled in a manner that protects human health and the environment. For more information about where you can drop off your waste equipment for recycling, please contact your local city office, your household waste disposal service or where you purchased the product.

July, 2005



## REACH Statement

### Registration of Substances

After careful review of the legislation and specifically the definition of an “article” as defined in EC Regulation 1907/2006, Title II, Chapter 1, Article 7.1(a)(b), it is our current view Multi-Tech Systems, Inc. products would be considered as “articles”. In light of the definition in § 7.1(b) which requires registration of an article only if it contains a regulated substance that “is intended to be released under normal or reasonably foreseeable conditions of use,” Our analysis is that Multi-Tech Systems, Inc. products constitute nonregisterable articles for their intended and anticipated use.

### Substances of Very High Concern (SVHC)

Per the candidate list of Substances of Very High Concern (SVHC) published October 28, 2008 we have reviewed these substances and certify the Multi-Tech Systems, Inc. products are compliant per the EU “REACH” requirements of less than 0.1% (w/w) for each substance. If new SVHC candidates are published by the European Chemicals Agency, and relevant substances have been confirmed, that exceeds greater than 0.1% (w/w), Multi-Tech Systems, Inc. will provide updated compliance status.

Multi-Tech Systems, Inc. also declares it has been duly diligent in ensuring that the products supplied are compliant through a formalized process which includes collection and validation of materials declarations and selective materials analysis where appropriate. This data is controlled as part of a formal quality system and will be made available upon request.

## Restriction of the Use of Hazardous Substances (RoHS)



**Multi-Tech Systems, Inc.**

### **Certificate of Compliance**

#### **2011/65/EU**

Multi-Tech Systems, Inc. confirms that its embedded products comply with the chemical concentration limitations set forth in the directive 2011/65/EU of the European Parliament (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment - RoHS).

These MultiTech products do not contain the following banned chemicals<sup>1</sup>:

- Lead, [Pb] < 1000 PPM
- Mercury, [Hg] < 1000 PPM
- Hexavalent Chromium, [Cr+6] < 1000 PPM
- Cadmium, [Cd] < 100 PPM
- Polybrominated Biphenyl, [PBB] < 1000 PPM
- Polybrominated Diphenyl Ether, [PBDE] < 1000 PPM

Environmental considerations:

- Moisture Sensitivity Level (MSL) =1
- Maximum Soldering temperature = 260C (in SMT reflow oven)

<sup>1</sup>Lead usage in some components is exempted by the following RoHS annex, therefore higher lead concentration would be found in some modules (>1000 PPM);

- Resistors containing lead in a glass or ceramic matrix compound.

## Information on HS/TS Substances According to Chinese Standards

In accordance with China's Administrative Measures on the Control of Pollution Caused by Electronic Information Products (EIP) # 39, also known as China RoHS, the following information is provided regarding the names and concentration levels of Toxic Substances (TS) or Hazardous Substances (HS) which may be contained in Multi-Tech Systems Inc. products relative to the EIP standards set by China's Ministry of Information Industry (MII).

### Hazardous/Toxic Substance/Elements

Name of the Component	Lead (PB)	Mercury (Hg)	Cadmium (CD)	Hexavalent Chromium (CR6+)	Polybrominated Biphenyl (PBB)	Polybrominated Diphenyl Ether (PBDE)
Printed Circuit Boards	O	O	O	O	O	O
Resistors	X	O	O	O	O	O
Capacitors	X	O	O	O	O	O
Ferrite Beads	O	O	O	O	O	O
Relays/Opticals	O	O	O	O	O	O
ICs	O	O	O	O	O	O
Diodes/ Transistors	O	O	O	O	O	O
Oscillators and Crystals	X	O	O	O	O	O
Regulator	O	O	O	O	O	O
Voltage Sensor	O	O	O	O	O	O
Transformer	O	O	O	O	O	O
Speaker	O	O	O	O	O	O
Connectors	O	O	O	O	O	O
LEDs	O	O	O	O	O	O
Screws, Nuts, and other Hardware	X	O	O	O	O	O
AC-DC Power Supplies	O	O	O	O	O	O
Software /Documentation CDs	O	O	O	O	O	O
Booklets and Paperwork	O	O	O	O	O	O
Chassis	O	O	O	O	O	O

**X** Represents that the concentration of such hazardous/toxic substance in all the units of homogeneous material of such component is higher than the SJ/Txxx-2006 Requirements for Concentration Limits.

**O** Represents that no such substances are used or that the concentration is within the aforementioned limits.

## Information on HS/TS Substances According to Chinese Standards (in Chinese)

### 依照中国标准的有毒有害物质信息

根据中华人民共和国信息产业部 (MII) 制定的电子信息产品 (EIP)

标准—中华人民共和国《电子信息产品污染控制管理办法》（第 39 号），也称作中国 RoHS, 下表列出了 Multi-Tech Systems, Inc. 产品中可能含有的有毒物质 (TS) 或有害物质 (HS) 的名称及含量水平方面的信息。

### 有害/有毒物质/元素

成分名称	铅 (PB)	汞 (Hg)	镉 (CD)	六价铬 (CR6+)	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
印刷电路板	O	O	O	O	O	O
电阻器	X	O	O	O	O	O
电容器	X	O	O	O	O	O
铁氧体磁环	O	O	O	O	O	O
继电器/光学部件	O	O	O	O	O	O
ICs	O	O	O	O	O	O
二极管/晶体管	O	O	O	O	O	O
振荡器和晶振	X	O	O	O	O	O
调节器	O	O	O	O	O	O
电压传感器	O	O	O	O	O	O
变压器	O	O	O	O	O	O
扬声器	O	O	O	O	O	O
连接器	O	O	O	O	O	O
LEDs	O	O	O	O	O	O
螺丝、螺母以及其它五金件	X	O	O	O	O	O
交流-直流电源	O	O	O	O	O	O
软件/文档 CD	O	O	O	O	O	O
手册和纸页	O	O	O	O	O	O
底盘	O	O	O	O	O	O

**X** 表示所有使用类似材料的设备中有害/有毒物质的含量水平高于 SJ/Txxx-2006 限量要求。

**O** 表示不含该物质或者该物质的含量水平在上述限量要求之内。

# Chapter 8 Labels

## Approvals and Certification

In most cases, when integrated and used with an antenna system that was part of the MultiTech modem certification, additional approvals or certifications are not required for the device you develop as long as the following are met.

- **PTCRB Requirements:** The antenna system cannot be altered.
- **Model Identification:** The MultiTech model identification allows the carrier to verify the modem as one of its approved models. This information is located on the modem's label below the bar code.

## Example Labels

**Note:** Actual labels vary depending on the regulatory approval markings and content.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

The label shown is not than actual size.

- 1 - MultiTech Model Identification.
- 2 - MultiTech Ordering Part Number.
- 3 - Device Node Number.

**Example North America Package Label**



**Example EMEA Package Label**



**North America Device Label**



**EMEA Device Label**



## Chapter 9 Developer Kit Overview

### Developer Board Overview

The MTUDK2-ST-MDOT Developer Kit supports development with mDot devices. Use the developer board to streamline your development efforts and evaluate your products and applications. Easily plug in your communications device and use the developer kit for testing, programming and evaluation.

**Note:** The MTUDK2-ST-Cell Developer Kit is also compatible with mDot devices. Developer information in this section applies to either of these developer board models when used with mDots. (The MTUDK2-ST-Cell model includes additional components which are used to develop with other devices.)

### Features

- USB and serial interfaces
- USB port for mbed development environment
- RS-232 DB-9 connector for serial interface
- Arduino shield socket

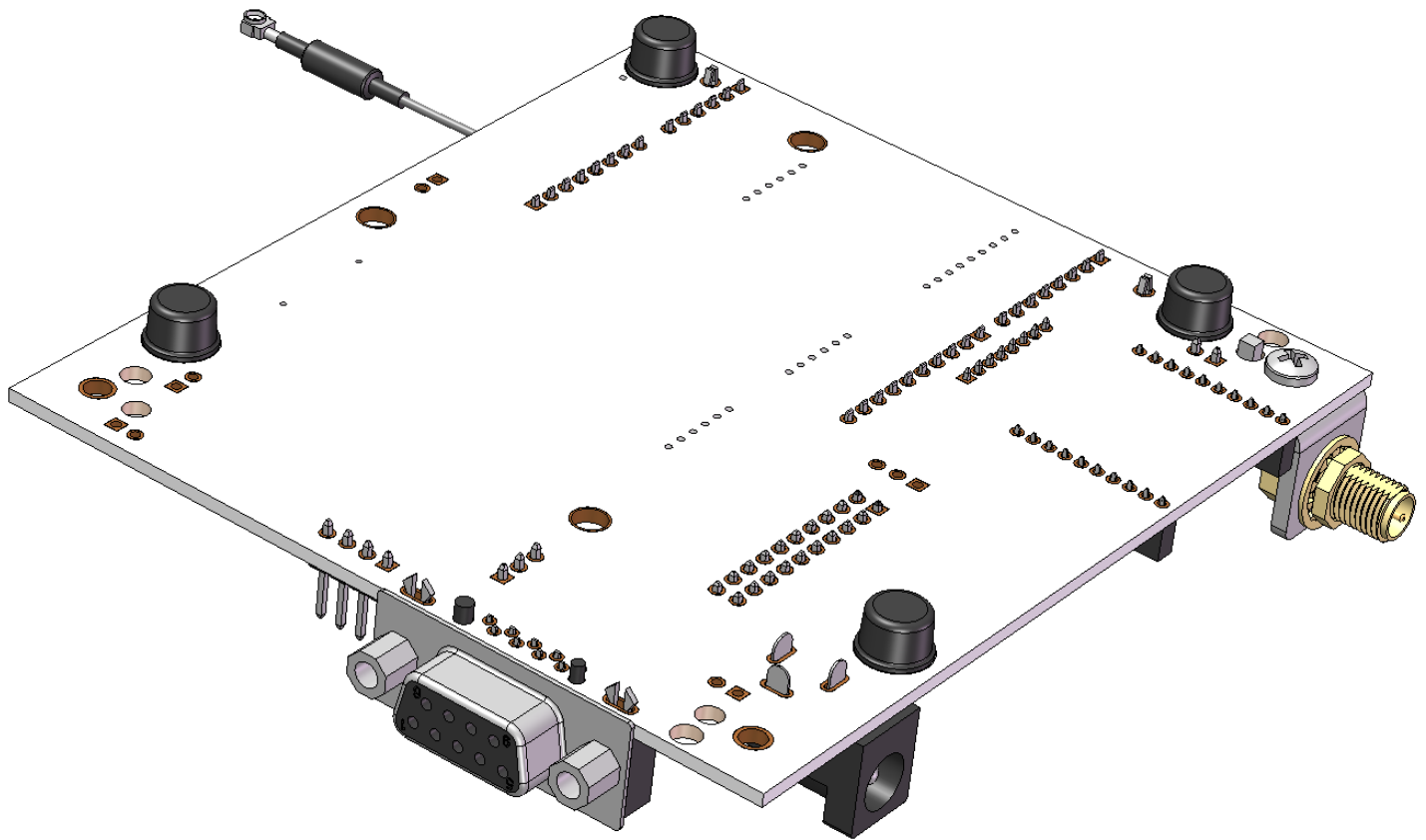
### Developer Kit Contents

Your Developer Kit (MTUDK2-ST-MDOT) includes the following:

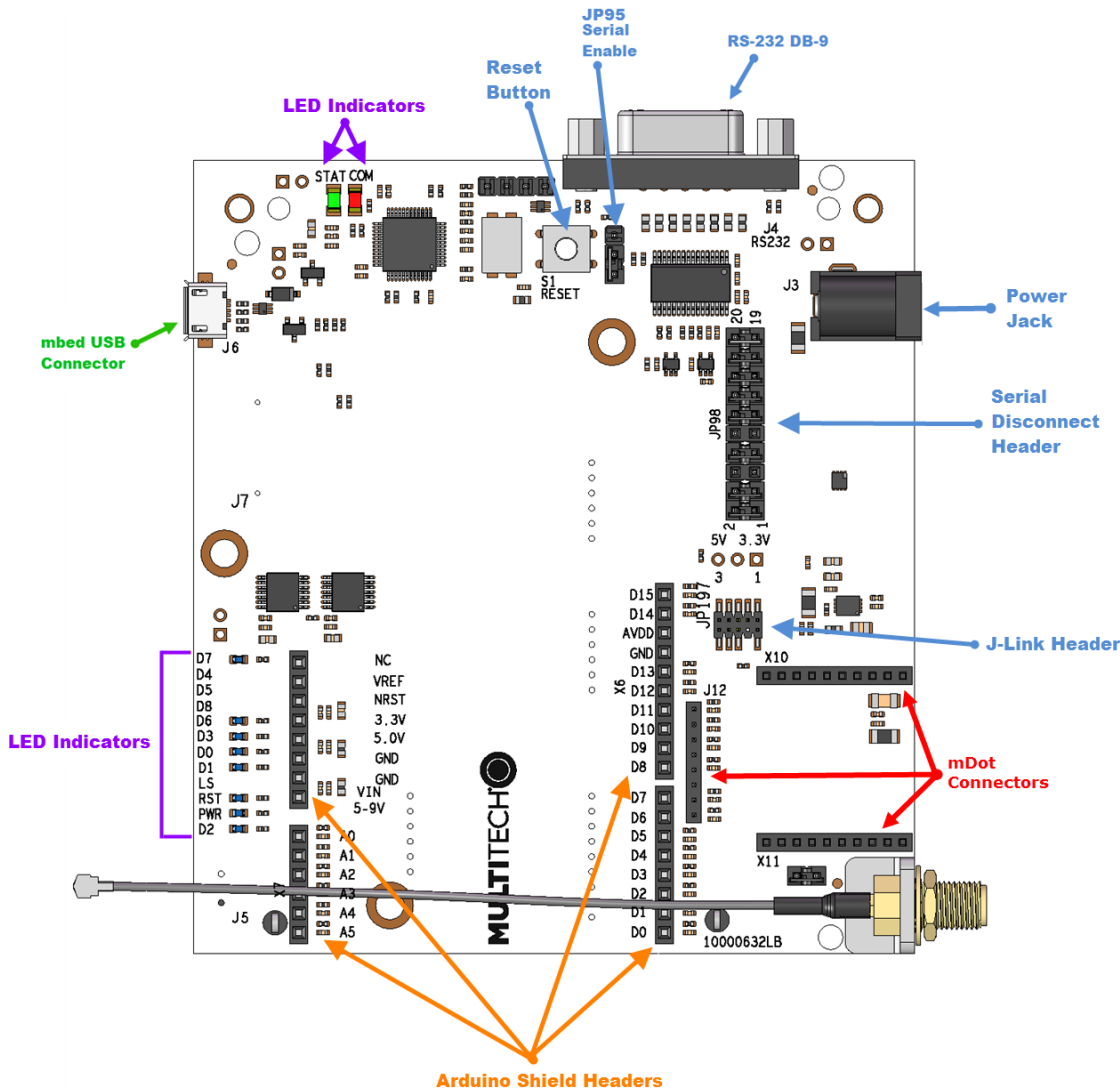
Developer Board	1 - MTUDK 2.0 mDot Developer Board
Cables	1 - Micro USB Cable
	1 - RSMA-U.FL Antenna Cables (attached to developer board)
Antennas	1 - 868-945 MHz Antenna
Customer Notices	Quick Start
Additional	One promotional screwdriver







## Developer Board Connectors



## Board Components

Label	Description
J4	RS232 DB-9 Serial Connector
J6	mbed USB Connector
JP98	Serial Disconnect Header
JP197	J-Link Header
S1	Reset Button
X6	Arduino Shield Connector
X7	Arduino Shield Connector

Label	Description
X8	Arduino Shield Connector
X9	Arduino Shield Connector
X10	MTDOT Connector
X11	MTDOT Connector
J12	MTDOT Programming Header

## LED Indicators

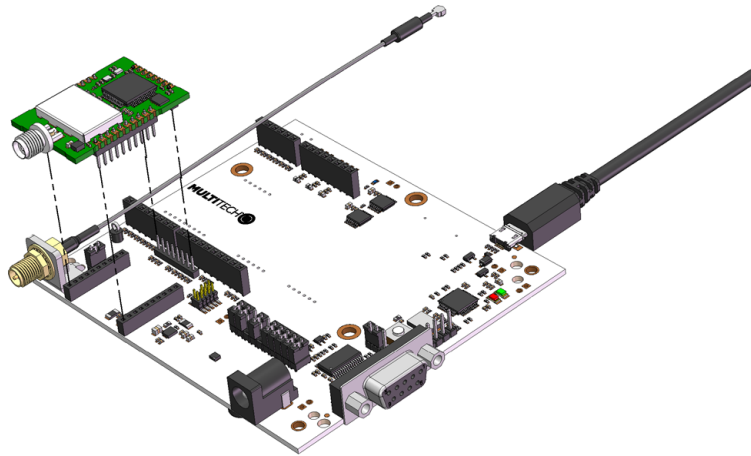
Label	LED	Location
STAT	LED1	Same side as RS-232 DB-9 connector
COM	LED2	Same side as RS-232 DB-9 connector
D7	LED3	Across the mDot connectors.
D6	LED7	Directly across from the mDot connectors.
D3	LED8	Directly across from the mDot connectors.
D0	LED9	Directly across from the mDot connectors.
D1	LED10	Directly across from the mDot connectors.
RST	LED12	Directly across from the mDot connectors.
PWR	LED13	Directly across from the mDot connectors.
D2	LED14	Directly across from the mDot connectors.

# Chapter 11 Developer Board Installation

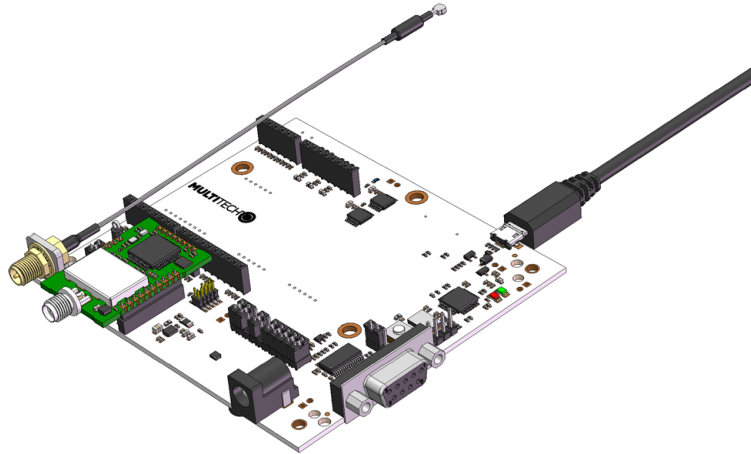
## Installing an mDot on the Developer Board

To install an mDot on the Developer Board:

1. Align the mDot with the developer board as shown.



2. Gently press the mDot into the connectors.



## Arduino Shield

### mDot Arduino Pins

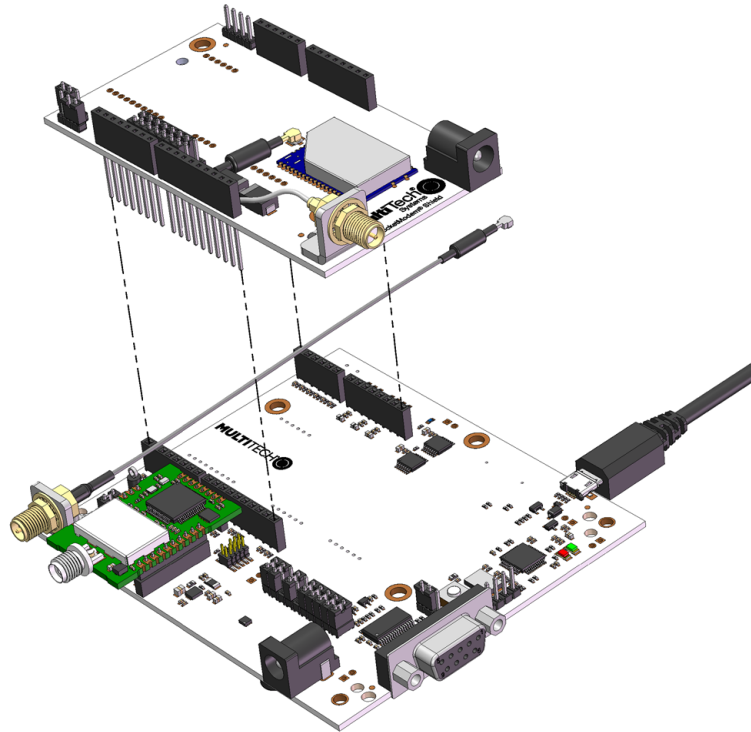
Signals (module pin) micro pin		Arduino Shield				Signals (module pin) micro pin	
					D15		PWM0/RSSI/I2CSCL (6) PA8
					D14		PWM1/I2CSDA (7) PC9
					AVDD		3.3V
					GND		Ground
					D13	X6	AD2/DIO2/SCK (18) PA5
3.3V			NC		D12		DO8/MISO (4) PA6
nReset, from pushbutton			VREF		D11		AD4/DIO4/MOSI (11) PA7
3.3V			nRST		D10		AD3/DIO3/SNSS (17) PA4
5.0V	X9		3.3V		D9		no connect
Ground			5.0V		D8		no connect
Ground			GND				
Ground			GND				
5-9V input from J3			VIN		D7		nDTR/SleepRQ/DI8 (9) PA11
					D6		nRTS/AD6/DIO6 (16) PA1
AD0/DIO0 (20) PB1					D5		no connect
AD1/DIO1 (19) PB0			A0		D4	X8	no connect
Associate/AD5/DIO5 (15) PC1	X7		A1		D3		nCTS/DIO7 (12) PA0
no connect			A2		D2		ON/nSleep (13) PC13
no connect			A3		D1		Dout (2) PA2
no connect			A4		D0		Din (3) PA3
			A5				

### Installing an Arduino Shield with an mDot

**Note:** When using an Arduino Shield with an mDot, install the mDot on the developer board before installing the Arduino shield.

To use an Arduino Shield with an mDot:

1. Disable the developer card's serial port by removing jumper from JP95.
  - Jumper pins 1-2: Disable U5 on USB VCC high.
  - Jumper pins 2-3: U5 always disabled.
  - Default jumper position is on pins 1-2.
2. Align the Arduino Shield on the developer board as shown.



## RSMA to U.FL Cables

The developer kit includes one 4.5" RSMA to U.FL cables which is preinstalled on the developer board.

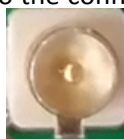


## Connecting an Antenna through the Developer Board Connectors

Depending on the mDot model, either connect the antenna directly to the mDot or through the RSMA-to-U.FL antenna cable on the developer board.

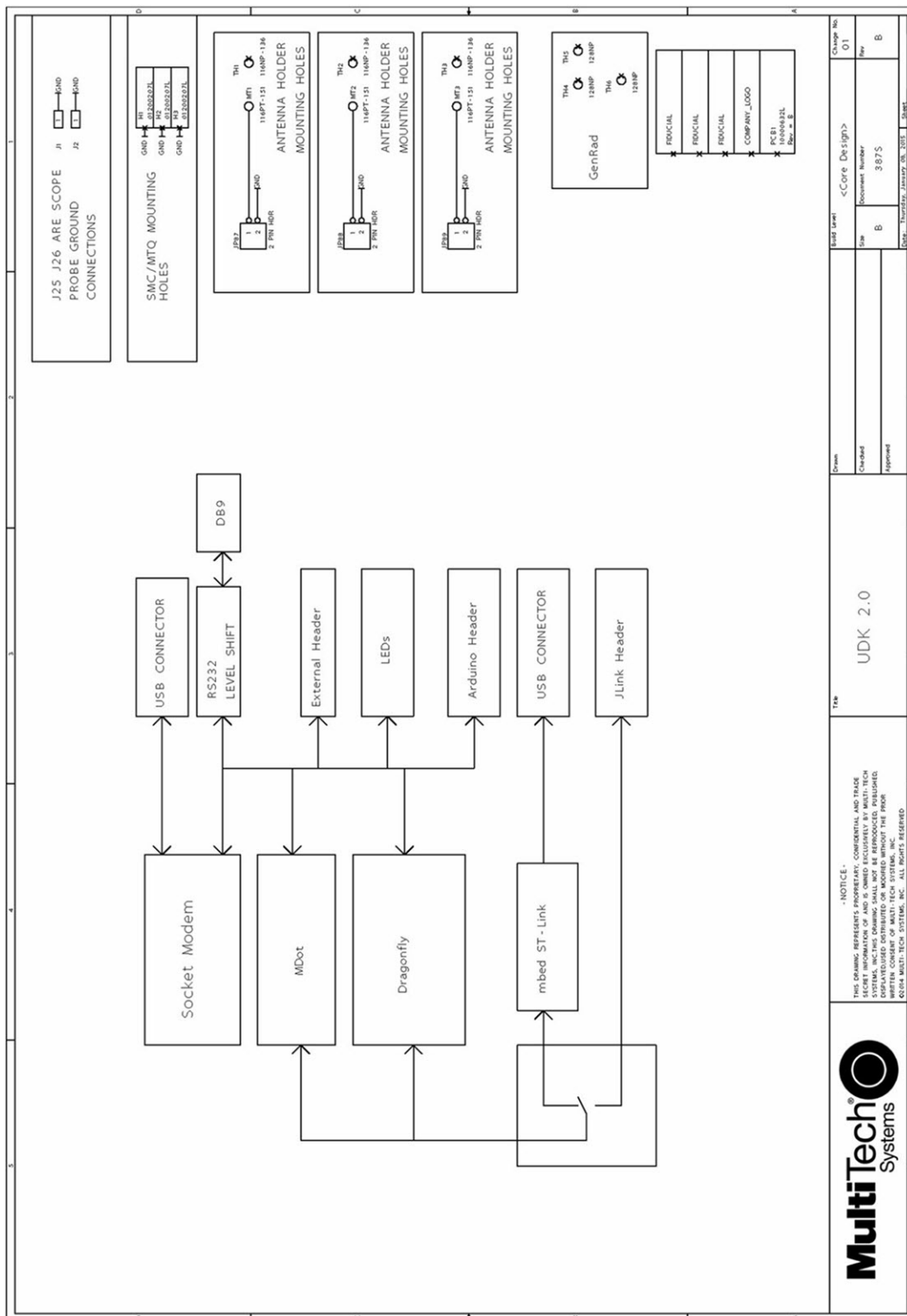
To connect an antenna to the device through the developer board :

1. Finger tighten the antenna to the SMA connector.
2. Attach the U.FL connector from the cable to the connector on the device.



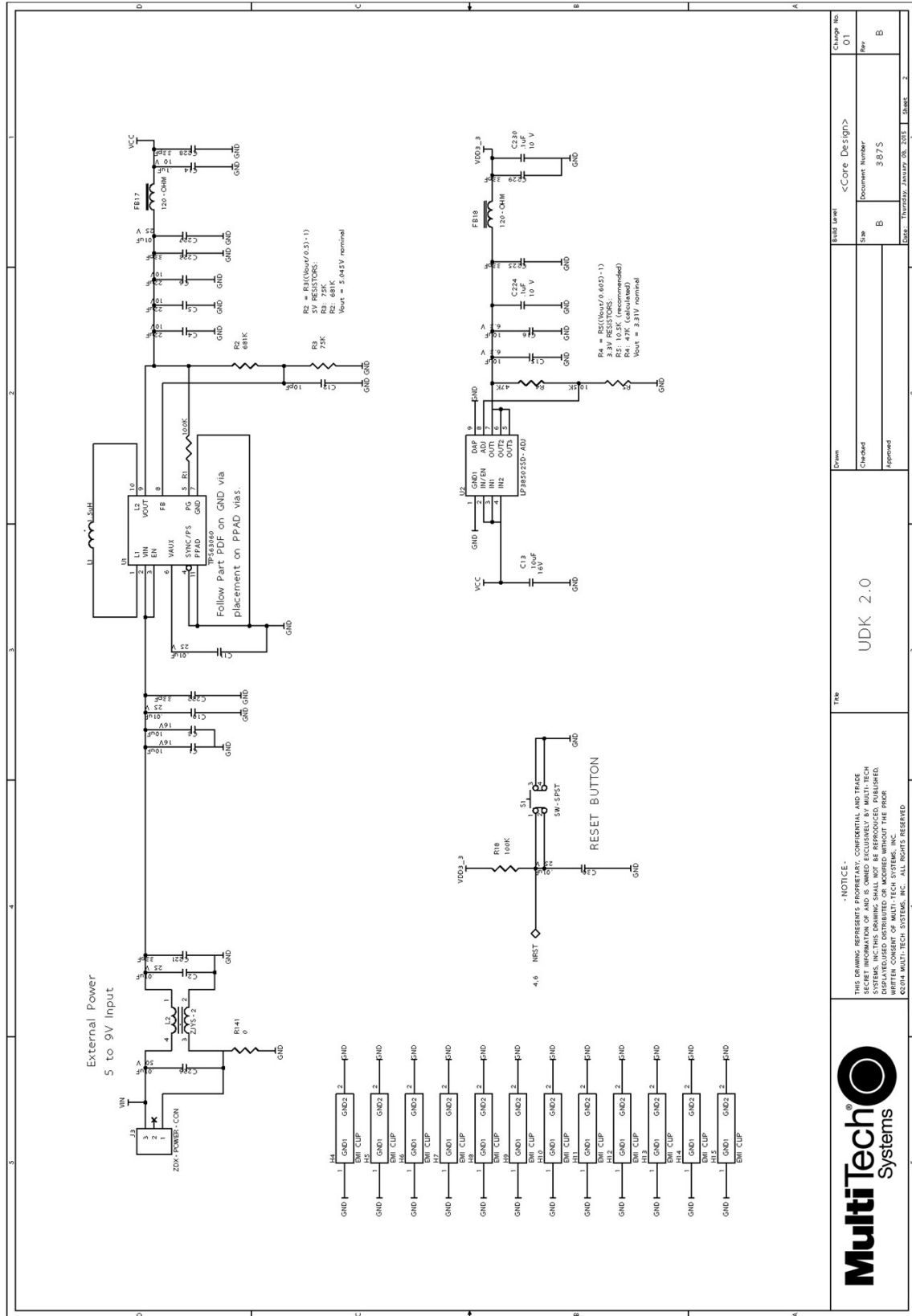
## Chapter 12 Developer Board Schematics

## Block Diagram

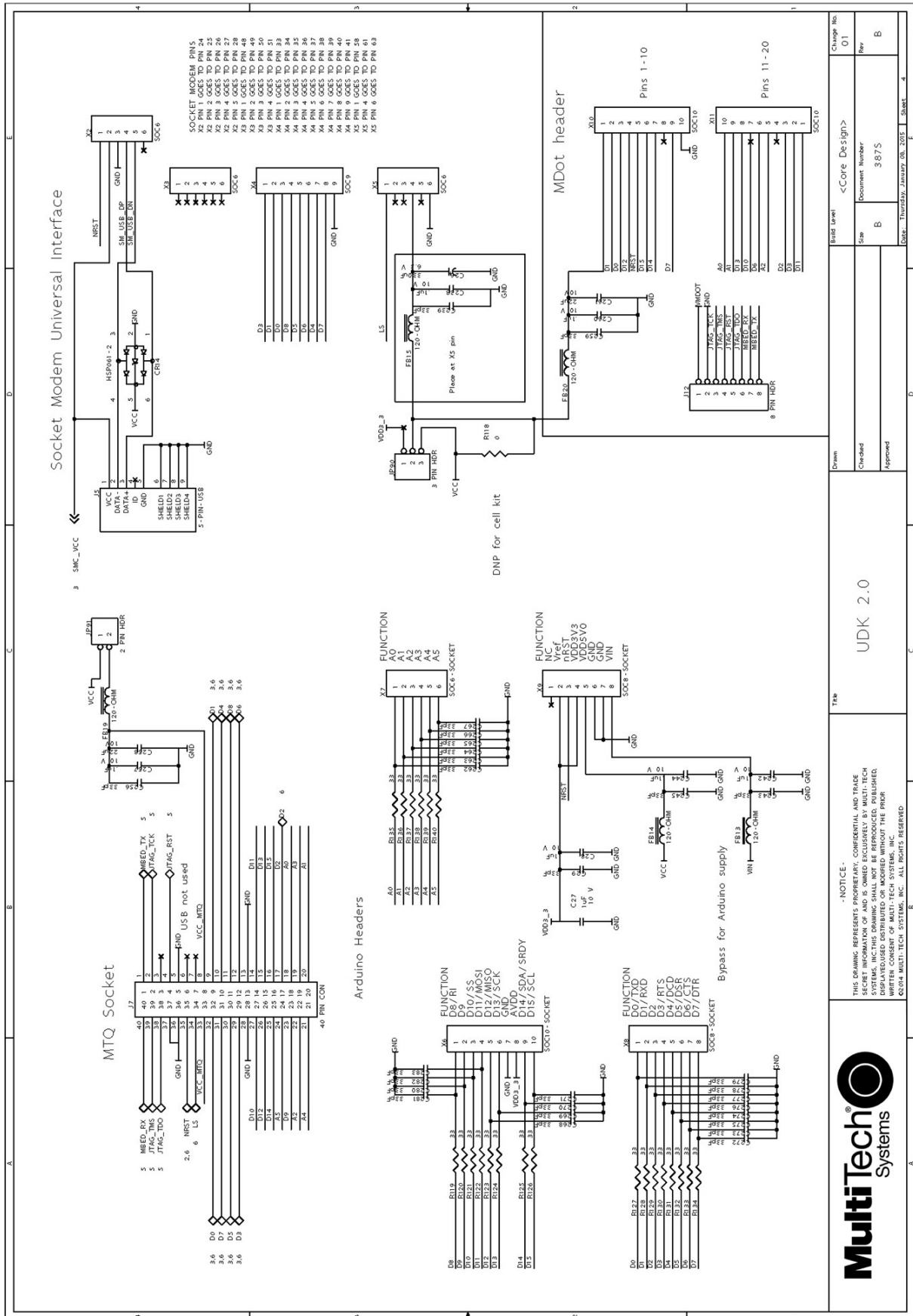




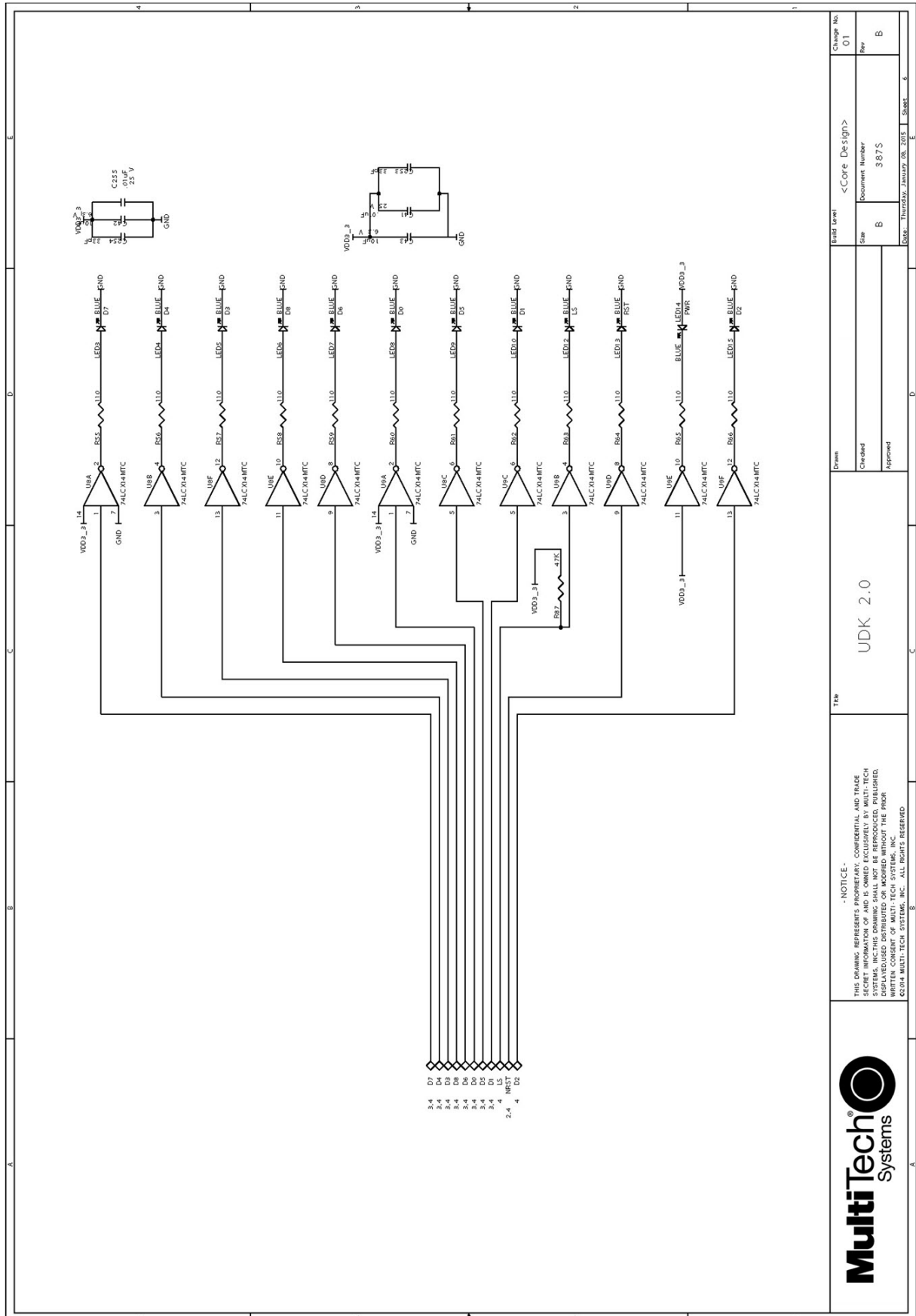
## Schematics











# Chapter 13 Design Considerations

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## Noise Suppression Design

Adhere to engineering noise-suppression practices when designing a printed circuit board (PCB). Noise suppression is essential to the proper operation and performance of the modem and surrounding equipment.

Any OEM board design must consider both on-board and off-board generated noise that can affect digital signal processing. Both on-board and off-board generated noise that is coupled on-board can affect interface signal levels and quality. Noise in frequency ranges that affect modem performance is of particular concern.

On-board generated electromagnetic interference (EMI) noise that can be radiated or conducted off-board is equally important. This type of noise can affect the operation of surrounding equipment. Most local government agencies have certification requirements that must be met for use in specific environments.

Proper PC board layout (component placement, signal routing, trace thickness and geometry, and so on) component selection (composition, value, and tolerance), interface connections, and shielding are required for the board design to achieve desired modem performance and to attain EMI certification.

Other aspects of proper noise-suppression engineering practices are beyond the scope of this guide. Consult noise suppression techniques described in technical publications and journals, electronics and electrical engineering text books, and component supplier application notes.

## PC Board Layout Guideline

In a 4-layer design, provide adequate ground plane covering the entire board. In 4-layer designs, power and ground are typically on the inner layers. Ensure that all power and ground traces are 0.05 inches wide.

The recommended hole size for the device pins is 0.036 in. +/-0.003 in. in diameter. Use spacers to hold the device vertically in place during the wave solder process.

All creepages and clearances for the device meet requirements of safety standards listed in the technical specifications. The requirements are based on a working voltage of 125V or 250V. When implementing the recommended DAA\* circuit interface in a third party design, strictly follow all creepage and clearance requirements to meet safety standards. The third party safety design must be evaluated by the appropriate national agency according to the required specification.

## User Accessible Areas

Based on where the third party design is marketed, sold, or used, it may be necessary to provide an insulating cover over all TNV exposed areas. Consult with the recognized safety agency to determine the requirements.

**Note:** Even if the recommended design considerations are followed, there are no guarantees that a particular system complies with all the necessary regulatory requirements. Make sure a qualified and recognized agency evaluates specific designs. .

\*DAA stands for Data Access Arrangement. DAA is the device's telephone line interface.

## Electromagnetic Interference

The following guidelines are offered specifically to help minimize EMI generation. Some of these guidelines are the same as, or similar to, the general guidelines. To minimize the contribution of device-based design to EMI, you must understand the major sources of EMI and how to reduce them to acceptable levels.

- Keep traces carrying high frequency signals as short as possible.
- Provide a good ground plane or grid. In some cases, a multilayer board may be required with full layers for ground and power distribution.
- Decouple power from ground with decoupling capacitors as close to the device's power pins as possible.
- Eliminate ground loops, which are unexpected current return paths to the power source and ground.
- Decouple the telephone line cables at the telephone line jacks. Typically, use a combination of series inductors, common mode chokes, and shunt capacitors. Methods to decouple telephone lines are similar to decoupling power lines; however, telephone line decoupling may be more difficult and deserves additional attention. A commonly used design aid is to place footprints for these components and populate as necessary during performance/EMI testing and certification.
- Decouple the power cord at the power cord interface with decoupling capacitors. Methods to decouple power lines are similar to decoupling telephone lines.
- Locate high frequency circuits in a separate area to minimize capacitive coupling to other circuits.
- Locate cables and connectors to avoid coupling from high frequency circuits.
- Lay out the highest frequency signal traces next to the ground grid.
- If using a multilayer board design, make no cuts in the ground or power planes and be sure the ground plane covers all traces.
- Minimize the number of through-hole connections on traces carrying high frequency signals.
- Avoid right angle turns on high frequency traces. Forty-five degree corners are good; however, radius turns are better.
- On 2-layer boards with no ground grid, provide a shadow ground trace on the opposite side of the board to traces carrying high frequency signals. This will be effective as a high frequency ground return if it is three times the width of the signal traces.
- Distribute high frequency signals continuously on a single trace rather than several traces radiating from one point.

## Electrostatic Discharge Control

Handle all electronic devices with precautions to avoid damage due to the static charge accumulation.

See the ANSI/ESD Association Standard (ANSI/ESD S20.20-1999) – a document “for the Development of an Electrostatic Discharge Control for Protection of Electrical and Electronic Parts, Assemblies and Equipment.” This document covers ESD Control Program Administrative Requirements, ESD Training, ESD Control Program Plan Technical Requirements (grounding/bonding systems, personnel grooming, protected areas, packaging, marking, equipment, and handling), and Sensitivity Testing.

MultiTech strives to follow these recommendations. Input protection circuitry is incorporated in MultiTech devices to minimize the effect of static buildup. Take precautions to avoid exposure to electrostatic discharge during handling.

MultiTech uses and recommends that others use anti-static boxes that create a faraday cage (packaging designed to exclude electromagnetic fields). MultiTech recommends that you use our packaging when returning a product and when you ship your products to your customers.

## USB Design

MultiTech recommends that you review Intel's High Speed USB Platform Design Guidelines for information about USB signal routing, impedance, and layer stacking. Also:

- Shield USB cables with twisted pairs (especially those containing D+/D-).
- Use a single 5V power supply for USB devices. See Power Draw for current (ampere) requirements.
- Route D+/D- together in parallel with the trace spacing needed to achieve 90 ohms differential impedance for the USB pair and to maintain a 20 mil space from the USB pair and all other signals.
- If power is provided externally, use a common ground between the carrier board and the device.



# Chapter 14 AT Commands

## MultiTech AT Command Set

### General Commands

Command	Description	Details
AT	Attention	Attention - returns OK
ATI	Request Id	Shows model, version info
ATZ	Reset CPU	Reset the CPU
ATE0/1	Enable/Disable echo mode	ATE0: disable, ATE1: enable
ATV0/1	Enable/Disable verbose mode	ATV0: disable, ATV1: enable
AT&F	Reset factory defaults	Reset current configuration to factory defaults
AT&W	Save configuration	Save configuration to flash memory
AT&V	Display status/setting	Displays current settings and status
AT+IPR	Set serial baud rate	Defaults to 115200
AT+DIPR	Set debug serial baud rate	Defaults to 115200
AT+SMODE	Start up mode	0: AT command mode, 1: Serial data mode

### Network/Addressing Commands

Command	Description	Details
AT+FREQ	Frequency Band	Set frequency band "868" or "915"
AT+FSB	Frequency Sub-band	Set the frequency sub-band for US 915, (0:ALL, 1-8)
AT+PN	Public Network	Enable/disable public network mode. (0: off, 1: on)
AT+DI	Device ID	Device EUI (unique, set at factory) (8 bytes)
AT+NA	Network Address	Network address (devAddr in LoraMac) (4 bytes)
AT+NSK	Network Session Key	Network session encryption key (16 bytes)
AT+DSK	Data Session Key	Data session encryption key (App session keyin LoraMac) (16 bytes)
AT+NK	Network Key	Configured network key/passphrase (App Key in LoraMac) ## AT+NK=0,hex AT+NK=1,passphrase (Net key = cmac(passphrase)) (16 bytes)
AT+NI	Network ID	Configured Network EUI/Name (App EUI in LoraMac) AT+NI=0,hex AT+NI=1,network_name (Net ID = crc64(network_name) (8 bytes)
AT+JOIN	Join Network	Join network (acquire network address and session keys)
AT+NJM	Network Join Mode	0: Manual configuration, 1: OTA Network Join, 2: Auto OTA Network Join on start up (default: 1)

Command	Description	Details
AT+NJS	Network Join Status	0: Not joined, 1: Joined (does this perform link check or just display last known state?)
AT+NLC	Network Link Check	Perform network link check (OK or ERROR)
AT+LCC	Link Check Count	Set number of packets between each link check if ACK's are disabled
AT+ENC	AES Encryption	Enable/disable AES encryption (0: off, 1: on)
AT+RSSI	Signal Strength	Displays signal strength of last received packet
AT+SNR	Signal To Noise Ratio	Display signal to noise ratio received packets last, minimum, maximum, average
AT+DP	Data Pending	Indicator of data in queue on server
AT+PING	Send Ping	Sends ping, displays RSSI and SNR from gateway on pong

## Radio Configuration

Command	Description	Details
AT+TXDR	Set Tx Datarate	Set the Tx spread factor for all channels (7-10)
AT+TXP	Set Tx Power	Set the Tx power for all channels
AT+TXF	Tx Frequency	Set Tx frequency
AT+TXCH	Set Tx Channel	TBD -- one channel or a list of channels? map frequencies to channel numbers? (0 = 902.7, 1 = 902.9, etc)
AT+TXI	Set Tx inverted	Set Tx signal inverted, (default:off)
AT+RXDR	Set Rx Datarate	Set the Rx spread factor for all channels (7-10)
AT+RXF	Rx Frequency	Set the Rx frequency for +RECV,+RECVC
AT+RXTO	Rx Timeout	Set the Rx timeout after a send in ms, default: 3000
AT+RXO	Rx Output	Set the Rx output type (0:hexadecimal, 1:binary)
AT+RXI	Set Rx inverted	Set Rx signal inverted, (default:on)
AT+FEC	Set Error Correction	Configure Forward Error Correction (1 to 4)
AT+CRC	Set CRC check on/off	Enable/disable CRC checking of received packets. (0: off, 1: on)
AT+ADR	Adaptive Data Rate	Enable/disable Adaptive Data Rate (0: off, 1: on)

## Send/Receive

Command	Description	Details
AT+ACK	Require Send ACK	Enable to require send acknowledgement (0: off, N: number of retries until ACK received)
AT+SEND	Send Once	Sends supplied packet data one time and return response

Command	Description	Details
AT+SENDB	Send Binary	Sends supplied binary (hex) packet data one time and return response
AT+SENDH	Send Once High BW	Sends supplied packet data one time and return response using High Bandwidth channel, (max:240 bytes)
AT+SENDI	Send Interval	Sends supplied packet data on interval (escape sequence: +++)
AT+RECV	Receive Once	Receive and display one packet (optional timeout argument: N milliseconds)
AT+RECV C	Receive Continuous	Continuously receive and display packets (escape sequence: +++)

### Serial data mode options

Command	Description	Details
AT+SD	Enter serial data mode	Reads serial data and sends Lora packets (escape sequence: +++)
AT+SDWI	Serial wake interval	Serial data wakeup interval to generate wake signal (milliseconds)
AT+SDTO	Serial receive timeout	Read serial data until timeout (milliseconds)
AT+SDWD	Serial Wake Delay	Time to wait for data after wakeup signal (milliseconds)

### MultiTech Debug

Command	Description	Details
AT+RR	Reset Radio	Reset the SX1272 radio
AT+SM	Set Radio Mode	Set SX1272 Radio Mode
AT+DREGS	Dump Regs	Dump the SX1272 register values
AT+ERASE	Erase entire flash	Erase all configurations saved in flash memory

## Standard XBee Zigbee AT Command Set

### Addressing Commands

Command	Description
AT	Attention
ATID	Personal Area Network ID
ATSH	High setting of 64-bit Address
ATSL	Low setting of 64-bit Address
ATDH	High setting of 64-bit Destination Address
ATDL	Low setting of 64-bit Destination Address

Command	Description
ATCN	Command Null
ATMY	My ID display
ATIT	Iteration Tailor
ATIA	Input address
ATNI	Node Identifier
ATSE	Source Endpoint
ATDE	Destination Endpoint
ATCI	Cluster Identifier
ATNP	Maximum RF payload bytes
ATDD	Device Type

## Networking Commands

Command	Description
ATCH	Operating Channel
ATOP	Operating Extended PAN ID
ATNH	Maximum Unicast Hops
ATBH	Maximum Broadcast Hops
ATOI	Operating PAN ID
ATNT	Node Discovery Timeout
ATNO	Node Discovery Options
ATSC	Scan Channels
ATSD	Scan Duration
ATZS	Zigbee Stack Profile
ATNJ	Node Join Time
ATJV	Channel Verification
ATNW	Network Watchdog Timeout
ATJN	Join Notification
ATAR	Aggregate Routing Notification

## Security Commands

Command	Description
ATEE	Encryption Enable
ATEO	Encryption Options
ATNK	Network Encryption Key

Command	Description
ATKY	Link Key

## RF Interfacing Commands

Command	Description
ATPL	Power Level
ATPM	Power Mode
ATDB	Received Signal Strength
ATPP	Peak Power

## Serial Interfacing Commands

Command	Description
ATAP	API Enable
ATAO	API Options
ATBD	Interface Data Rate
ATNB	Serial Parity
ATSB	Stop Bits
ATRO	Packetization Timeout
ATDx	Pin Configurations
ATIR	Set sample rate of I/O pins
ATIC	I/O Digital Change Detection
ATPx	PWM0/Digital Pin Configuration
ATLT	Associate LED Blink Time
ATPR	Configure pull-up resistors
ATRP	RSSI PWM Timer
AT%V	Display current supply voltage
ATV+	Voltage Supply Monitoring
ATTP	Read Module Temperature

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